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Contribution from the Bureau of Entomology, L. O. Howard, Chief, and the Bureau of Plant Industry, Wm. A. Taylor, Chief.

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A METHOD OF FUMIGATING SEED.[1]

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INTRODUCTION.

A perfectly reliable method of destroying insects present in seeds imported into this country, without injury to the seed, is much needed. The exclusion of insects by a careful selection of apparently uninfested seeds at the port of export is impracticable, because many injurious insects pass their larval and pupal stages and a portion of the adult stage inclosed within the seed and on this account might easily escape notice when the seeds were inspected. Furthermore, seeds are frequently received from localities where injurious insects are not well recognized, and, also, insects which are only slightly injurious in their native habitats occasionally become destructive pests when established in this country.

The ordinary methods of destroying insects in stored seeds, such as subjecting them to heat (with or without moisture), carbon bisulphid, and hydrocyanic acid in the presence of air, have been tried and found unsatisfactory for this purpose.

It occurred to the writers to create a partial vacuum in the container in which the seeds had been placed and fill the chamber with some gaseous insecticide, such as carbon bisulphid or hydrocyanic acid, in the belief that a much larger amount of gas might thus be forced into the crevices of the seeds and into the insect galleries than would be possible if the entrance of the gas were dependent upon diffusion under normal atmospheric pressure. This method was successfully used with a number of different kinds of seeds and insects, and a convenient chamber, described later, was devised for fumigation under reduced pressure.

[1] This work was carried on in cooperation between the Federal Horticultural Board and the Office of Plant Physiological and Fermentation Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.

FUMIGATION CHAMBER.

The fumigation chamber (fig. 1 and fig. 2, *b*) is of iron tubing, 36 inches long by 12 inches in diameter. One end of this cylinder is permanently closed with a heavy iron cap (fig. 1, *a*). The other end is fitted with a flange and can be closed with a brass plate (fig. 1, *b*), which is held in place by clamps. One face of the plate is ground to fit the flange, which is also ground. A wide rubber gasket is placed between the two faces when the plate is clamped in position. The chamber is designed to lie with its longest axis in a horizontal position. On the side of the chamber intended to lie uppermost three openings are made, one being in the center and one at each end. The opening

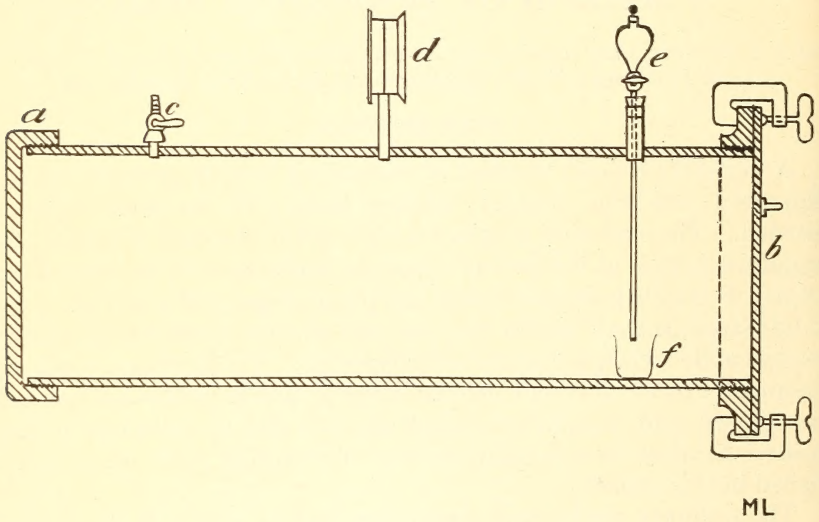

FIG. 1.—Diagram of fumigation chamber: *a*, Iron cap; *b*, brass plate clamped on end of chamber; *c*, gas cock for attaching suction hose; *d*, vacuum gauge; *e*, dropping funnel, by means of which the sulphuric acid is introduced into the chamber; *f*, beaker to contain cyanid.

near the capped end is fitted with a gas cock (fig. 1, *c*), so that the suction hose of a vacuum pump can be readily attached. A vacuum gauge, registering the decrease in pressure in units equivalent to inches of mercury, is placed in the center opening (fig. 1, *d*), while a tubulature is placed in the opening near the flange. The tubulature is closed with a perforated rubber stopper bearing a dropping funnel (fig. 1, *e*) so arranged that the bulb and stopcock are outside the chamber, while the tube extends down inside the chamber nearly to the bottom. The rubber stopper and dropping funnel can be readily removed when seeds or other material to be fumigated are placed in the chamber. An air pump, driven by a motor and capable of reducing the air pressure to the equivalent of about 0.05 of a millimeter of mercury, is used to secure an almost complete vacuum (fig. 2, *a*).

When this apparatus is used for fumigation, the seeds, contained in either a cloth bag or an open vessel, are placed in the chamber, and the requisite amount of sodium or potassium cyanid in a small beaker is so arranged that the neck of the dropping funnel extends down into the beaker (fig. 1, *f*). The cover is then clamped on and the chamber exhausted. In extracting the air from the chamber, the suction is continued until the gauge registers 30 inches or more—that is, the air in the chamber is exhausted until the pressure is the equivalent of some fraction of an inch of mercury. The suction is then cut off by means of the gas cock, and the required quantity of diluted acid, which has been previously placed in the bulb of the

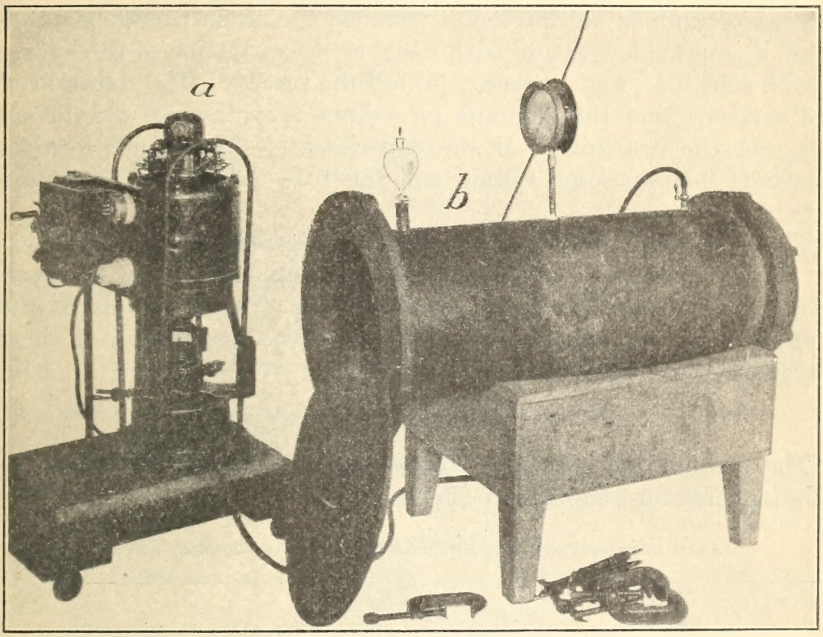

FIG. 2.—Air pump (*a*) and fumigation chamber (*b*) used in the experiments described in this bulletin.

dropping funnel, is allowed to flow slowly upon the cyanid in the beaker within the chamber. The hydrocyanic acid is thus prepared in the chamber and no trace can get out. After the seeds are exposed to the gas for the required time, the stopcock of the dropping funnel is opened to let the air into the chamber. As the discharge pipe of the air pump extends outside the building, the mixture of hydrocyanic acid and air can not escape into the room. As soon as convenient, the stopper and funnel are removed and, by means of the air pump, air is sucked through the chamber, thus washing the hydrocyanic acid out of the chamber before the cover is taken off and the seeds removed. In the experiments described

here the seeds were examined carefully at several different times to see whether all insects were killed. The viability of the seeds was then tested.

Part of the germination tests recorded in this paper were made by Mr. W. R. Lucas, of the Office of Foreign Seed and Plant Introduction, but in most cases tests with treated and untreated seeds were carried out by Mr. W. L. Goss, of the Seed Laboratory of the Bureau of Plant Industry.

In these experiments the duration of the exposure and the concentration of hydrocyanic acid were varied in order to determine the minimum exposure and concentration of hydrocyanic acid which would insure the death of all the infesting insects. It was also considered of interest to determine whether the seeds would be uninjured if exposed longer and with a higher concentration of the hydrocyanic acid than that necessary to kill the insects. The duration of the exposure and the amounts of sodium or potassium cyanid are given in the description of the experiments. The 1–1–2 formula was used for potassium cyanid and the 1–1½–2 formula for sodium cyanid.

The iron fumigation chamber already described was used in most of the experiments. In some of the preliminary work, however, desiccators or bell jars were used instead. The essentials of the method were the same in either case, and no description of these pieces of apparatus seems necessary.

EXPERIMENTS.

The summarized results of these experiments are here given in tabular form for comparison (Table I).

TABLE I.—*Summary of experiments in fumigating against insects.*

Material.	Infested with—	Kind of cyanid and amount used.	Time of exposure.	Result.	Germination test.
Avocado:			*Hrs.*		
26 seeds.	One adult avocado weevil (*Heilipus lauri*).	Sodium cyanid, ½ gm., in desiccator.	1	Insect dead.....	22 out of 26 seeds germinated.
29 seeds.	.....	.....do.....	½	.....	20 out of 29 seeds germinated; 21 out of 25 germinated in control test.
5 seeds..	Larvæ of avocado weevil (inclosed in a cotton-plugged vial) and broad-nosed grain weevil (*Caulophilus latinasus*).	.....do.....	½	All stages dead....	Seed cut up to determine mortality of insects and not planted.
20 seeds.	.....	.....do.....	6	.....do.....	No germination.
Do...	.....	.....do.....	12	.....do.....	Do.
6 seeds..	Larvæ of Conotrachelus sp. and broad-nosed grain weevil, all stages.	Sodium cyanid, 4 gms.	½	.....do.....	All seeds germinated.
10 seeds.	.....do.....	.....do.....	¼	No insects alive out of 50 examined of all stages.	Do.

TABLE I.—*Summary of experiments in fumigating against insects*—Continued.

Material.	Infested with—	Kind of cyanid and amount used.	Time of exposure.	Result.	Germination test.
			Hrs.		
Avocado:					
7 seeds..	Larvæ of Conotrachelus sp. and broad-nosed grain weevil, all stages.	Sodium cyanid, 2 gms.	¼	1 grain-weevil larva alive.	Not planted.
6 seeds..	4 with all stages of broad-nosed grain weevil; 2 uninfested.	...do.....	½	All stages dead....	3 seeds planted and all germinated.
10 seeds.	Scolytid.....	.....do.....	½	Out of several hundred specimens 1 live adult was found.	Not planted.
Do....	.....do.....	Sodium cyanid, 4 gms.	½	All stages dead....	Do.
Sorghum seed.	Bruchus sp.....	Sodium cyanid, 2 gms.	¼	Insects alive.....	75.5 per cent germination; seed badly infested.
Do.....	Bruchus sp. and rice weevil (*Calandra oryza*).	Sodium cyanid, 4 gms.	½	All stages dead....	71 per cent germination; seed badly eaten.
Do.....	.....do.....	.....do.....	1	.....do.....	83 per cent germination.
Do.....	Rice weevil and cadelle (*Tenebroides mauritanicus*).	Sodium cyanid, ½ gm., in desiccator.	½	.....do.....	Of four grades fumigated, the percentage of germination was as follows: 78.5; 86.5; 88; 83.
Do.....	.....do.....	.....do.....	1	.....do.....	Germination of fumigated seed superior to that of untreated seed.
Do.....	Rice weevil.....	Potassium cyanid, 2 gms.	30	.....do.....	Seed thoroughly infested with insects previous to fumigating and only 15 per cent germinated.
Bulbs.....	Bulb mite (*Rhizoglyphus hyacinthi*).	Sodium cyanid, ½ gm., in desiccator.	1	All mites dead....	Bulbs thoroughly infested and unfit for planting.
Cotton seed.	Adults of the red grain beetle (*Cathartus gemellatus*).	Sodium cyanid, 1½ gms.	1	All insects dead....	Not planted.
Gleditsia sinensis in seed pods.	Bruchus sp. (adults)..	Sodium cyanid, 2 gms.	½	All insects dead, both in and out of seed pods.	Percentage of germination approximately the same with both fumigated and untreated seed.
Do.....	.....do.....	Sodium cyanid, 4 gms.	½	.....do.....	Do.
Phaseolus vulgaris.	Bruchus sp.....	Sodium cyanid, ½ gm., in desiccator.	1	All insects dead...	Germination of fumigated seed superior to that of untreated seed.
Pineapples.	Pseudococcus sp.....	.....do.....	½	.....do.....	Not planted.
Tussock moth (*Hemerocampa leucostigma*):					
500 egg masses.	.....	Sodium cyanid, 2 gms.	½	Some larvæ hatched several days after exposure.	
250 egg masses.	.....	Sodium cyanid, 4 gms.	½	No hatching.....	

The results given in Table I indicate that the fumigation of seeds by the introduction of hydrocyanic acid into an air-tight chamber, from which the air has been practically exhausted, is effective, provided the exposure is not less than half an hour. An exposure of one-fourth hour is effective with the apparatus employed in these experiments if four or more grams of cyanid are used.

SUMMARY.

Fumigation by the method described in this bulletin was found to kill insects without injury to the seed and with a considerably shorter exposure than is necessary in the usual method of seed-fumigation. Further experiments will be conducted with special reference to the use of carbon bisulphid, which is not considered in this paper.

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